

Demultiple

At the end of this Session, you will be able to:

- **Define the terms primary energy and multiple energy as used in data processing.**
- **Define the terms multiple order and period as used in processing.**
- **Define the following water bottom multiple, free surface multiple, peg-leg multiple and internal multiple**
- **Produce a diagram that shows the travel path of each of the following multiple types: water bottom multiple, free surface multiple, peg-leg multiple, internal multiple**

Primary and Multiple energy

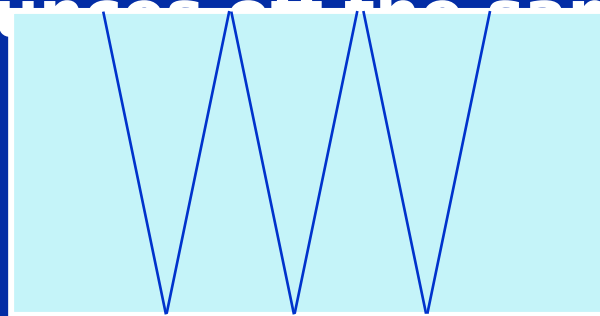
- **Primary energy is energy which has been reflected only once, and so is a true image of the reflector from which it arose**
- **Multiples are events reflected more than once**
- **Multiples hinder interpretation**
 - **False events**
 - **Incorrect amplitudes**
- **Multiples can be very difficult.....**
 - **to identify**
 - **to remove**

General Properties of Multiples

- **Low velocity (high moveout)**
 - **Velocity increases with depth**
- **High amplitude**
 - **less geometric spreading**
- **Periodic**
 - **Repeated cycles in horizontal layers**
- **Predictable**
 - **From primaries**

Multiple Order

- This is the number of additional bounces that a seismic wave has undergone in addition to the original primary reflection.
- Therefore, a second-order multiple is a signal that has undergone a primary reflection plus two additional bounces off the same layer.

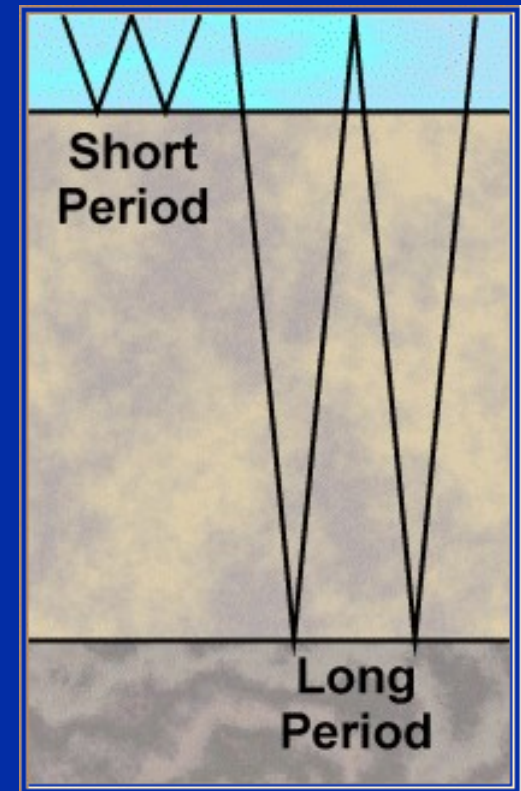


Multiple Period

- This is the time between each successive bounce of the multiple series.
- Multiple periods are generally classified into three types:
 - 1.Short
 - 2.Intermediate
 - 3.Long

Multiple Period

- Short period multiples generally have a period of 100 or 200 msec. They can usually be removed using short operator deconvolution.
- Long period multiples generally have a period of 1/2 second or longer. They can usually be removed using long operator deconvolution.
- Intermediate period multiples fall directly between these two types. Also, they are generally characterised by the fact that they



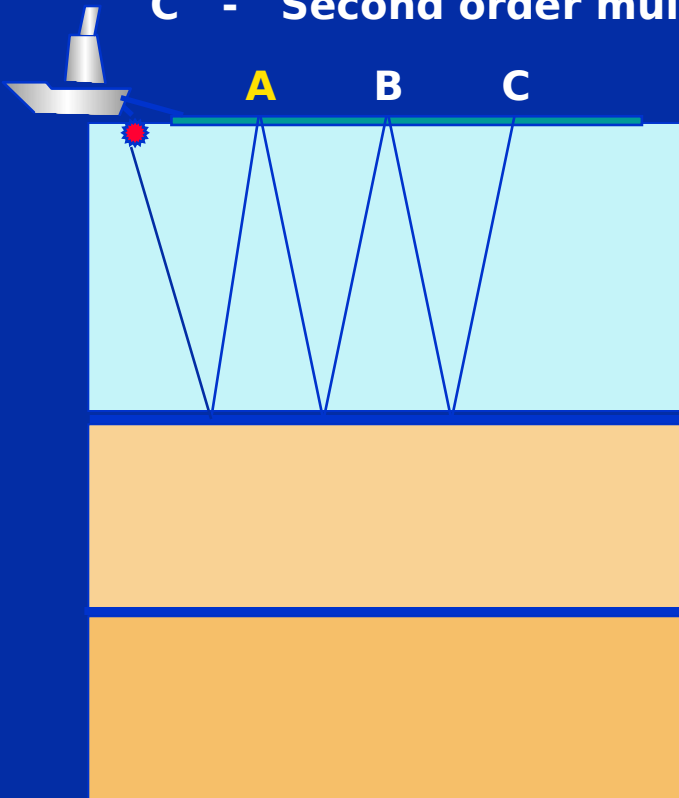
Order of Multiples

Event recorded, dependent on receiver position:

A - Primary

B - First order multiple

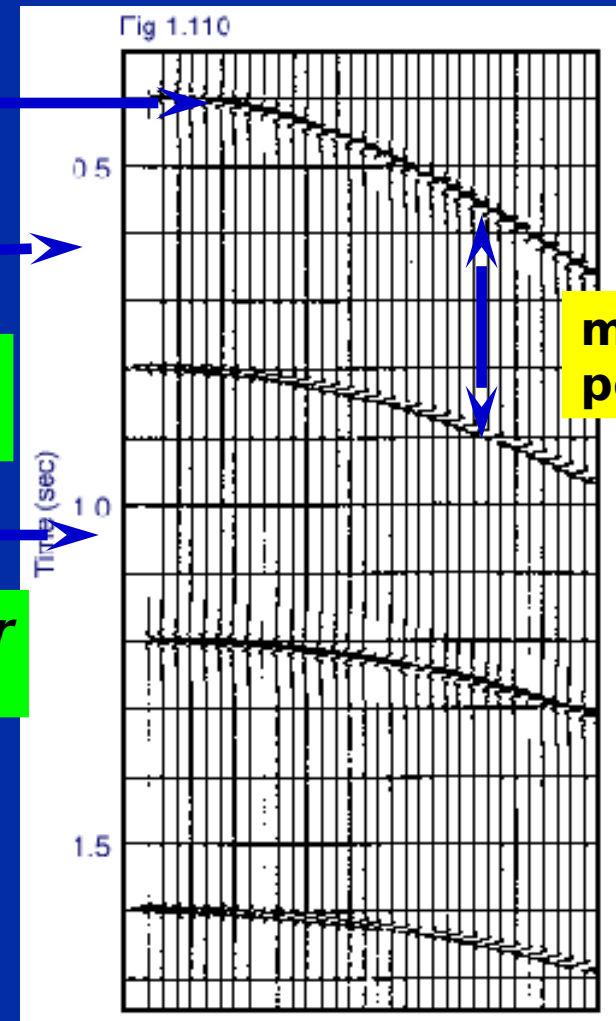
C - Second order multiple



primary

1st order multiple

2nd order multiple



Water Bottom Multiple

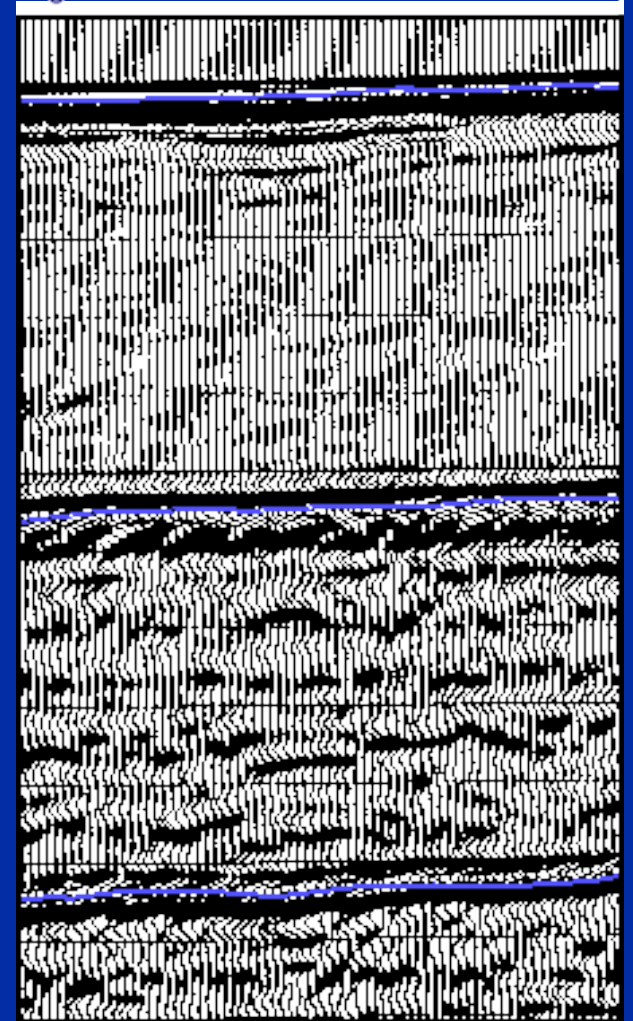
- An extremely common source of multiple reflection occurs in marine seismic work because of the presence of the water layer.
- This is because both the water/air interface and the water bottom are characterized by having a large change in acoustic impedance.
- These large reflection coefficients cause a high proportion of the seismic energy to be trapped in the water layer, and allows little signal to be transmitted into the earth.



Water-bottom
multiple

Water Bottom Multiple

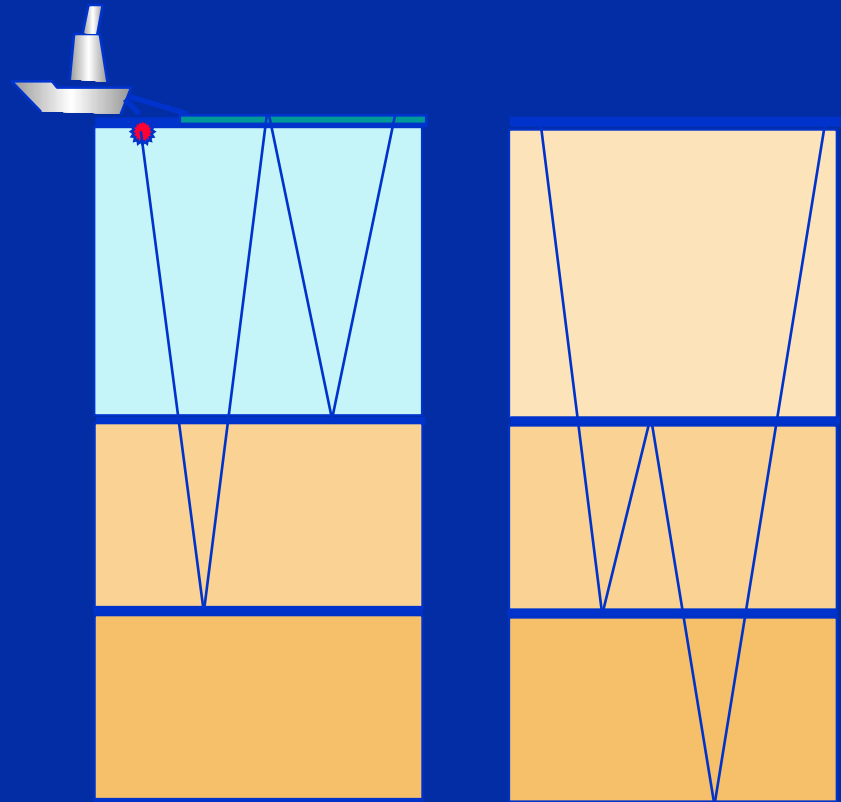
The reflection coefficient of the water/air interface approximates to -1, so as can be seen, the polarity of the signal changes after each reflection from this interface (ie. there is a 180° phase change at each reflection).



Pegleg Multiple

- Just as the water layer acts as a direct source of strong multiples, so may it also act as a source of multiple reflections for primary reflections which arise within the earth itself.

- In this case the multiples that are generated are referred to as peg-leg multiples, because of their characteristic ray paths.

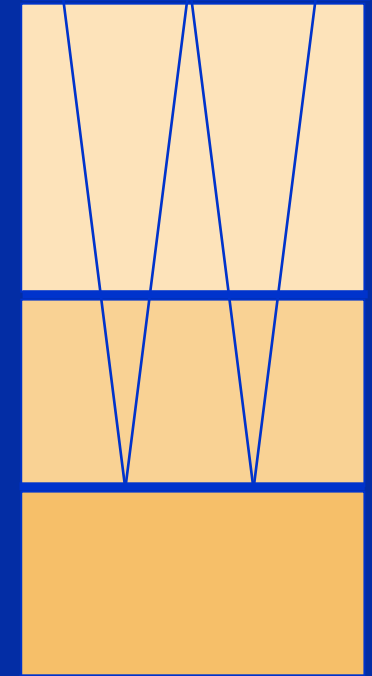


Water-bottom
pegleg multiple

Pegleg
Multiple

Free Surface Multiple

- An impedance contrast occurs at the land/air boundary in land acquisition just as at the water/air boundary in marine acquisition.
- Again as in marine case the reflection coefficient of the air/land surface interface approximates to -1, so the polarity of the signal changes after each reflection from this interface (ie. there is a 180° phase change at each reflection).

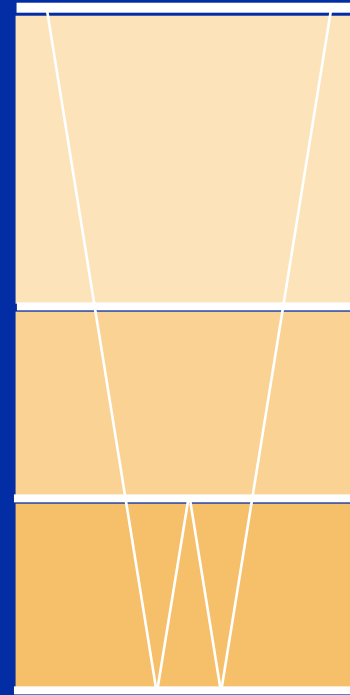


**Free-surface
multiple**

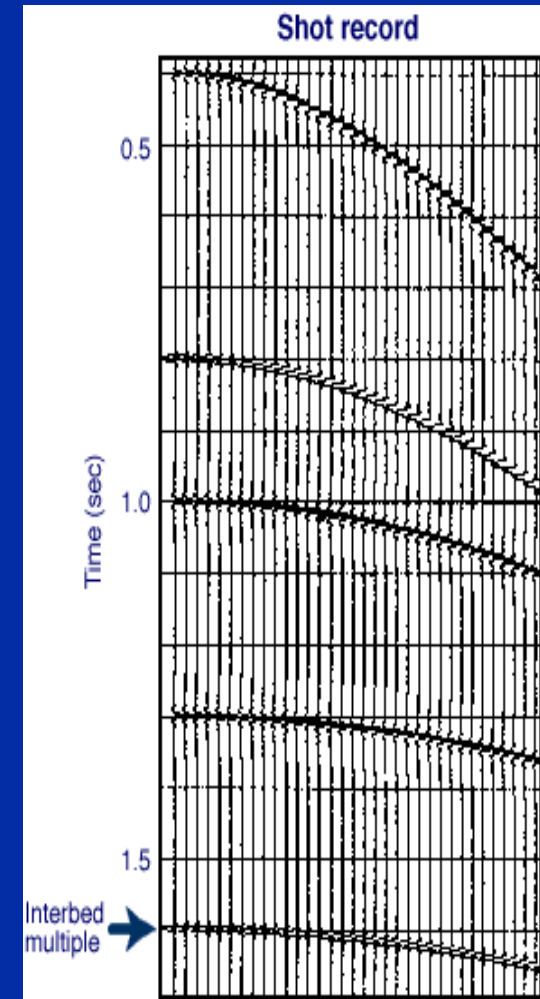
Internal Multiple

- The only prerequisite for multiples to occur is that there should be at least two strong reflectors.
- Therefore, multiples may arise within the earth at any interface, provided that the two reflectors have "large" reflection coefficients

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Inter-bed or
internal
multiple



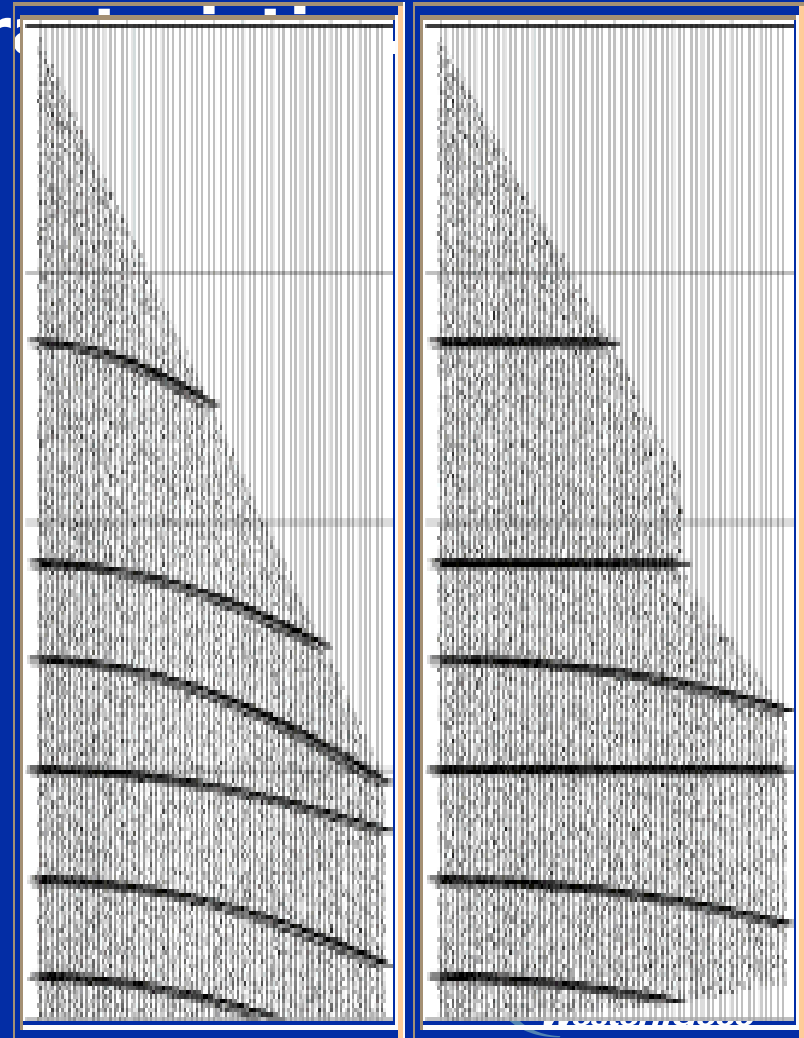
At the end of this Session, you will be able to:

- **Describe how to distinguish primaries from multiple events using their velocity.**
- **Describe the removal of multiples using stack.**
- **Describe the removal of multiples using fk demultiple.**
- **Describe the transforming of events into the tau-p domain.**
- **Describe the removal of multiples using tau-p demultiple.**
- **Define the following terms PRT, p traces, moveout range and mute range.**
- **Describe the removal of multiples using wave equation demultiple.**

Removal of multiples

The removal of multiples generally relies on either or both of two recognisable characteristics:

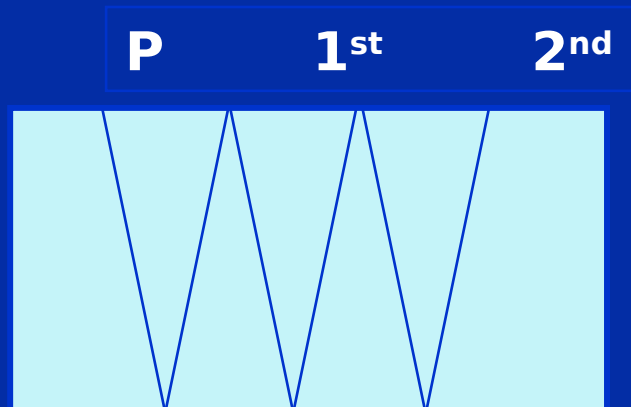
- Multiples will generally go on and on, repeating with the same time interval and gradually decreasing in amplitude (think of repeated "bounces" of energy in a water layer).
- Multiples will generally appear on our CDP gathers with a velocity slower than the primary velocity at the same time. They will have



Primary and Multiple Velocity

- As the primary and multiple energy has both travelled through the same layer the multiple just spent longer in the layer, then what's their velocity relationship?

They have the same velocity



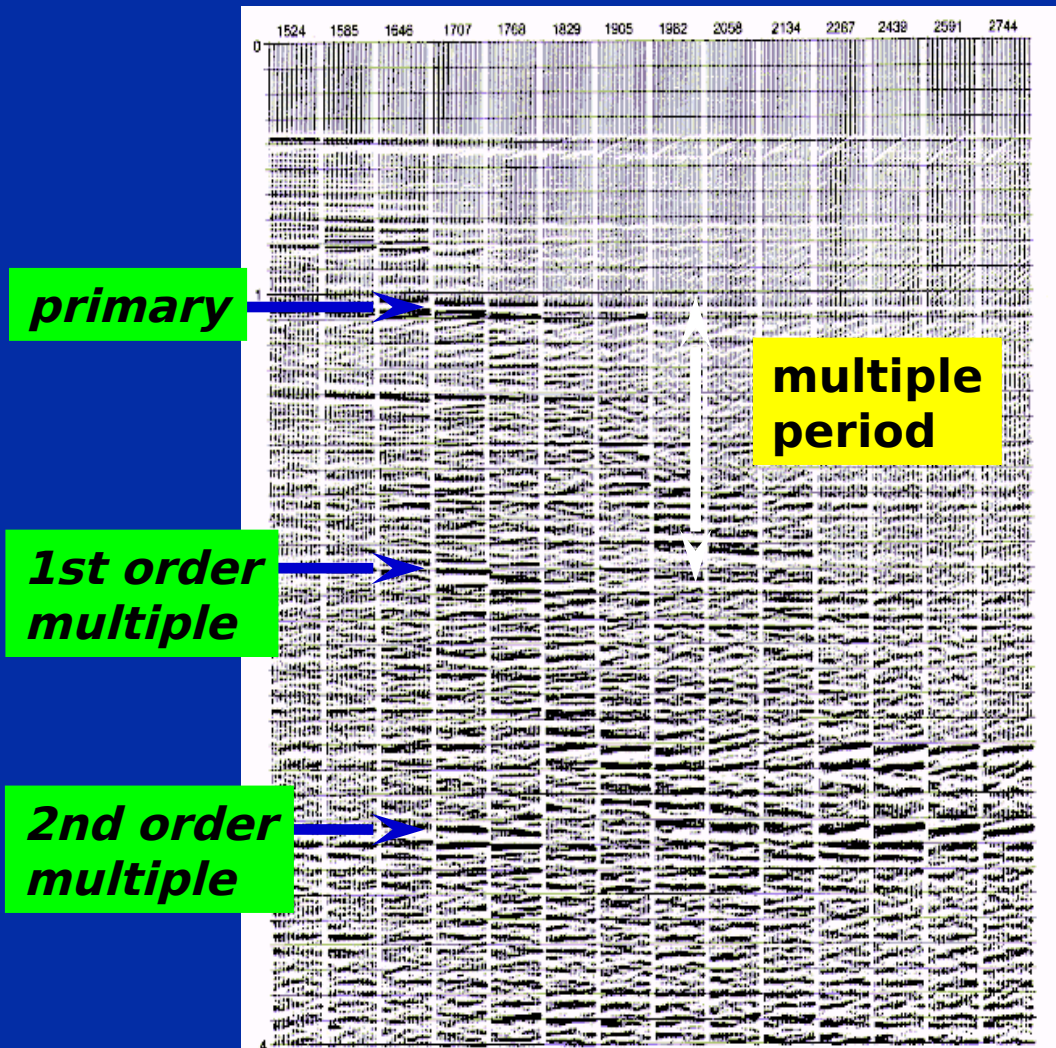
Velocity

So looking at our constant velocity stack we can recognise a multiple as having the same velocity as the primary.

We will see the same thing on our semblance display where multiples will appear directly below primaries.

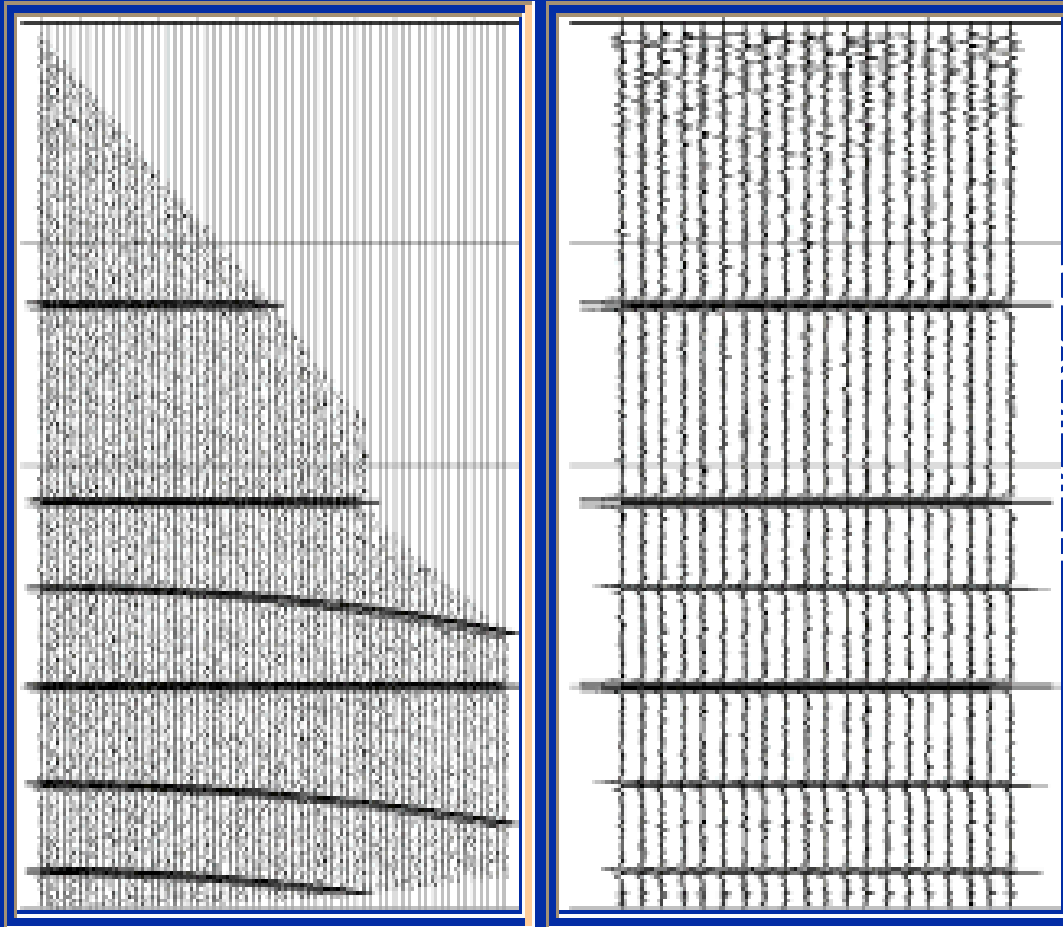
But as we know velocity should increase the further into the earth you go so multiples will have a slower velocity than the events surrounding them.

Constant Velocity Stack (CVS)



As we have seen they will

Stack



CMP stack of nmo corrected gathers will result in enhancement of the primary energy and degradation of the multiple energy.

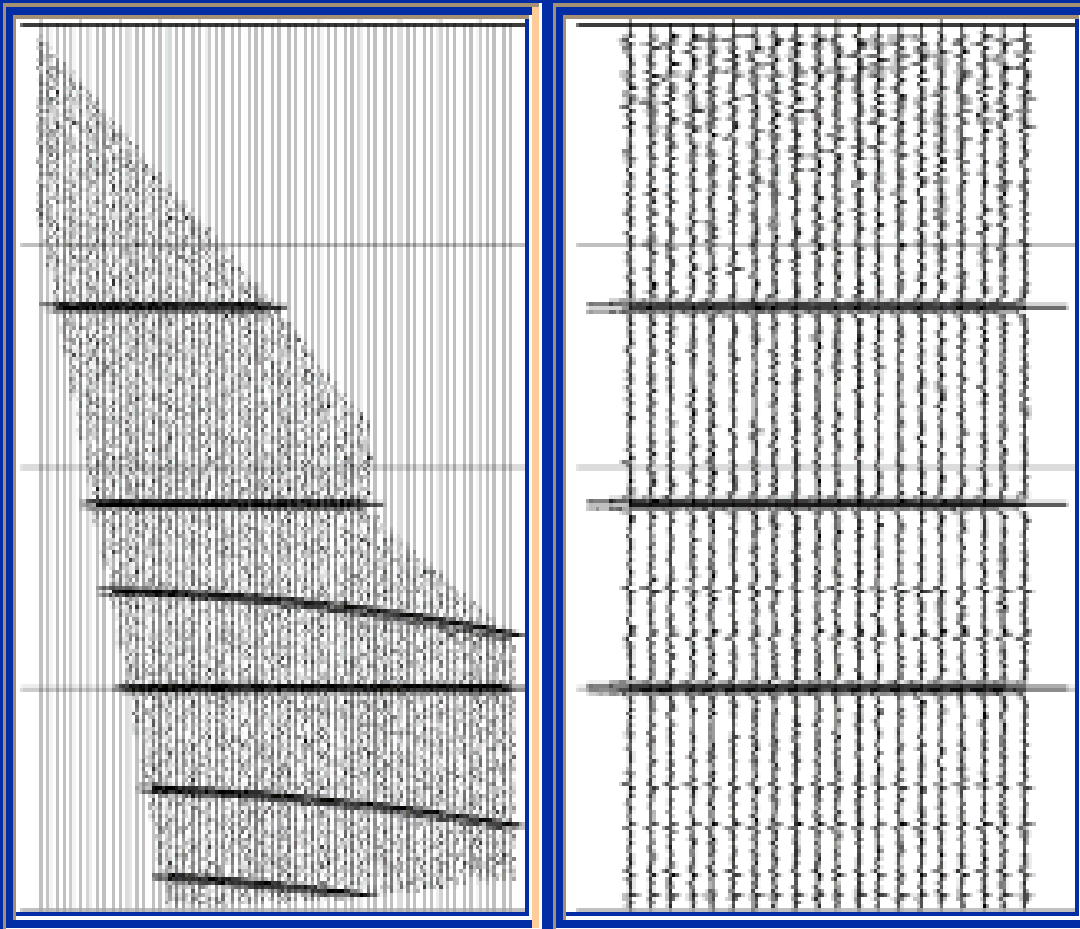
**CMP gather and stack after
NMO correction using primary
velocity function**

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2004

Stack

- ✓ **Easy**
- ✓ **Cheap**
- ✓ **Improves S/N**
- × **Incomplete multiple suppression**
- × **Output is poststack - limited AVO available**

Near Trace Mute

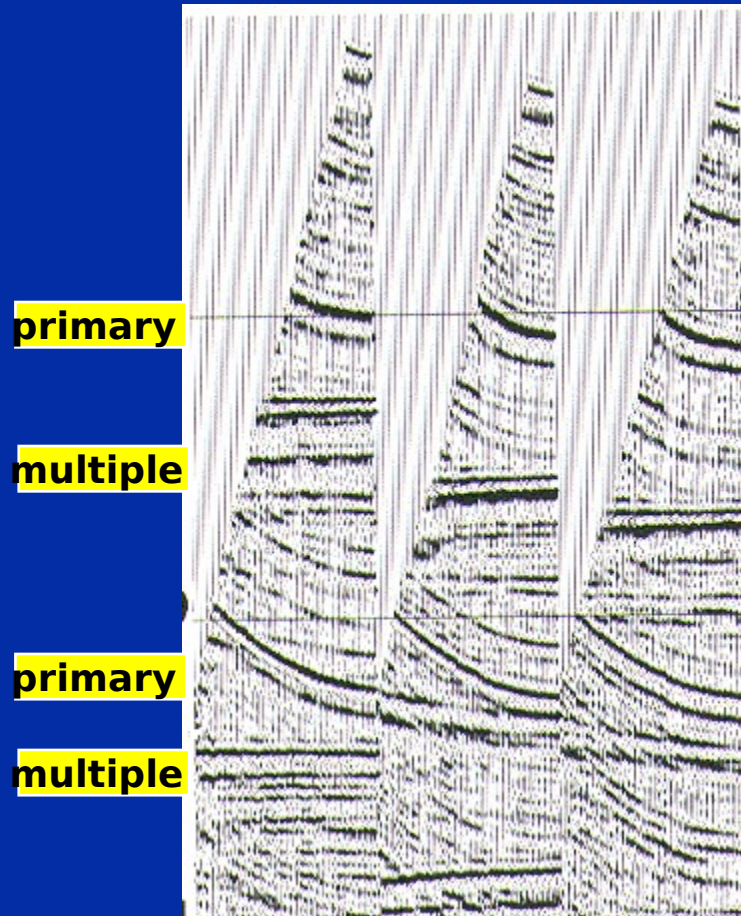


Removing the near traces from our cmp gather results in further degradation of the multiples. As the multiple event appears flattest on the near traces and so stacks up best for the near traces.

**CMP gather and stack after
NMO correction using primary
velocity function**

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2004

FK demultiple



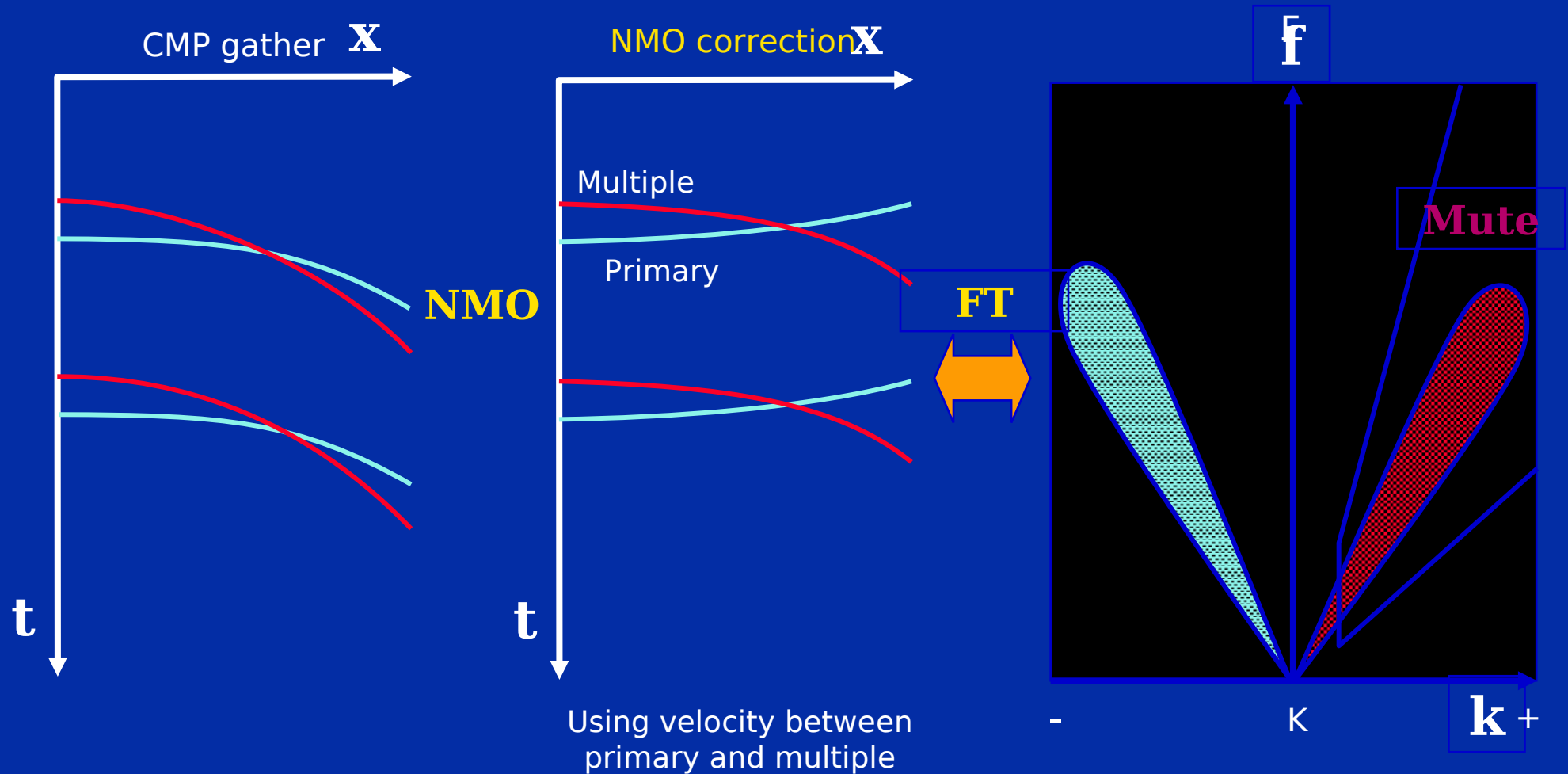
**CMP gathers after NMO correction
using multiple velocity function**

1. The normal procedure is to overcorrect the primaries while leaving the multiples undercorrected.

2. Transform to FK domain.

**3. Remove all events at $K > 0$
i.e. all multiple energy muted.**

FK demultiple



FK demultiple

✓ Easy

✓ Cheap

× Requires regular offsets

× Poor on near offsets - amplitude effects

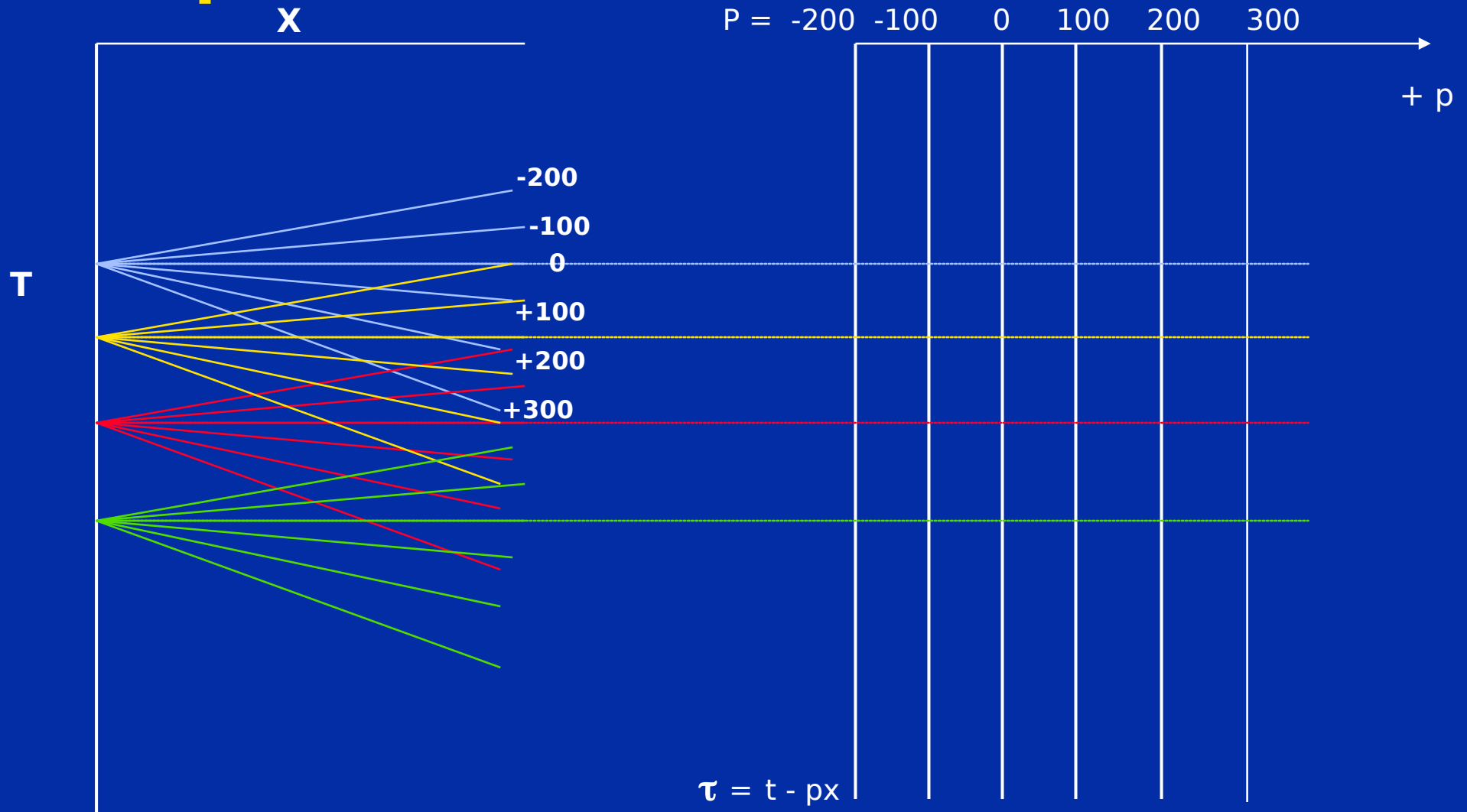
× Suffers from aliasing

Radon Transform

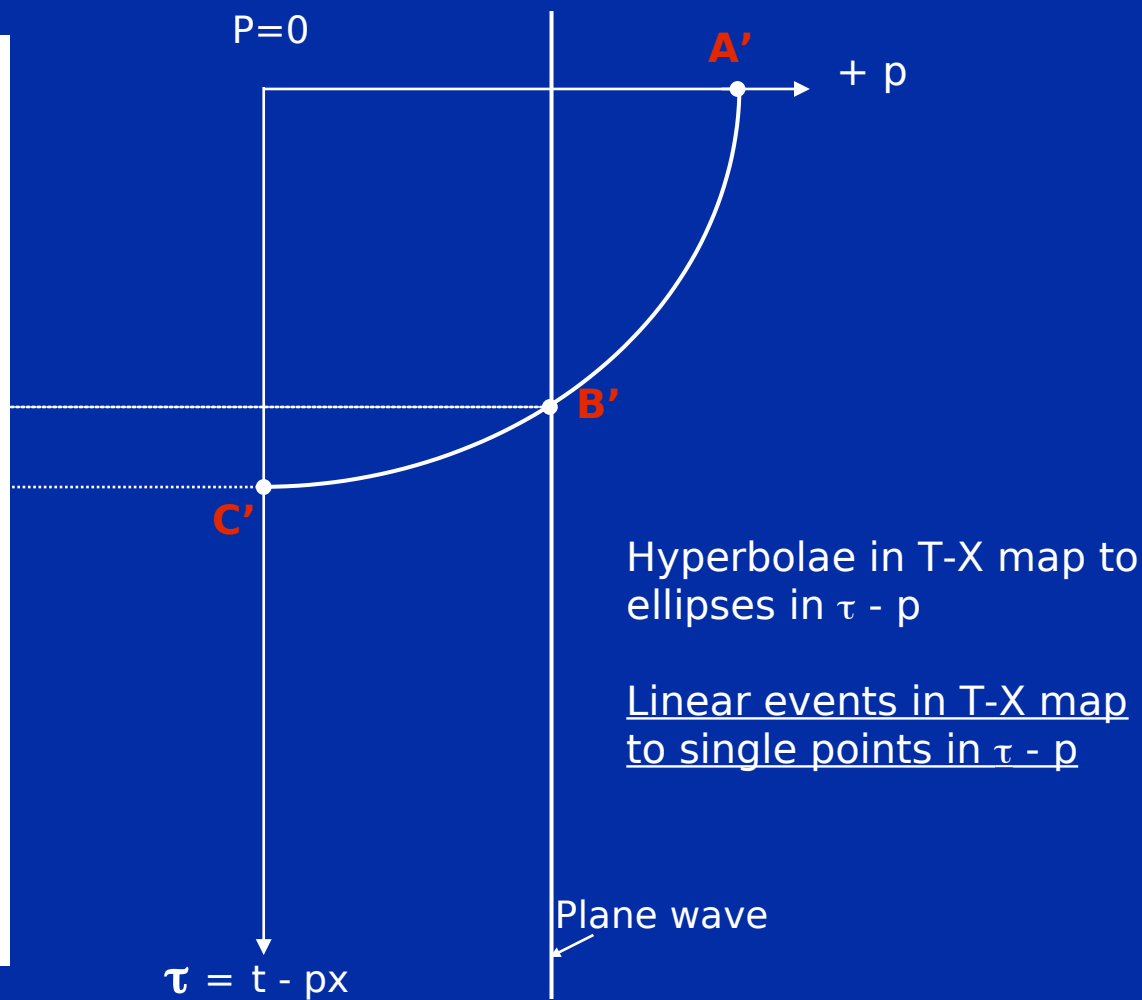
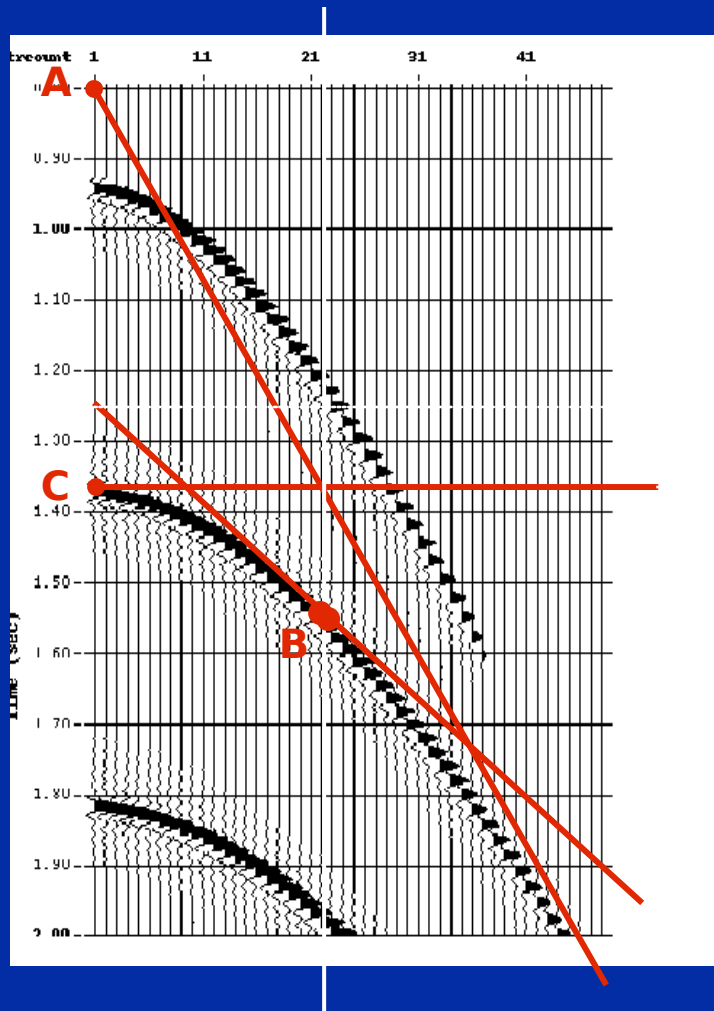
- Radon transform is a way of transforming data from the x - t domain into the Tau- p domain
- Radon transform is a multi-channel process which involves summing amplitudes along events in the x - t domain to transform them into the Tau- p domain
- The trajectories along which the amplitudes are summed can be Linear, Parabolic or Hyperbolic. Depending on the type of transformation, we give the names:

- Linear Radon Transform
 - Parabolic Radon Transform (PRT)
 - Hyperbolic Radon Transform
- (Each converts data to 'Tau- p domain')

Tau-p Domain



Tau-p Domain

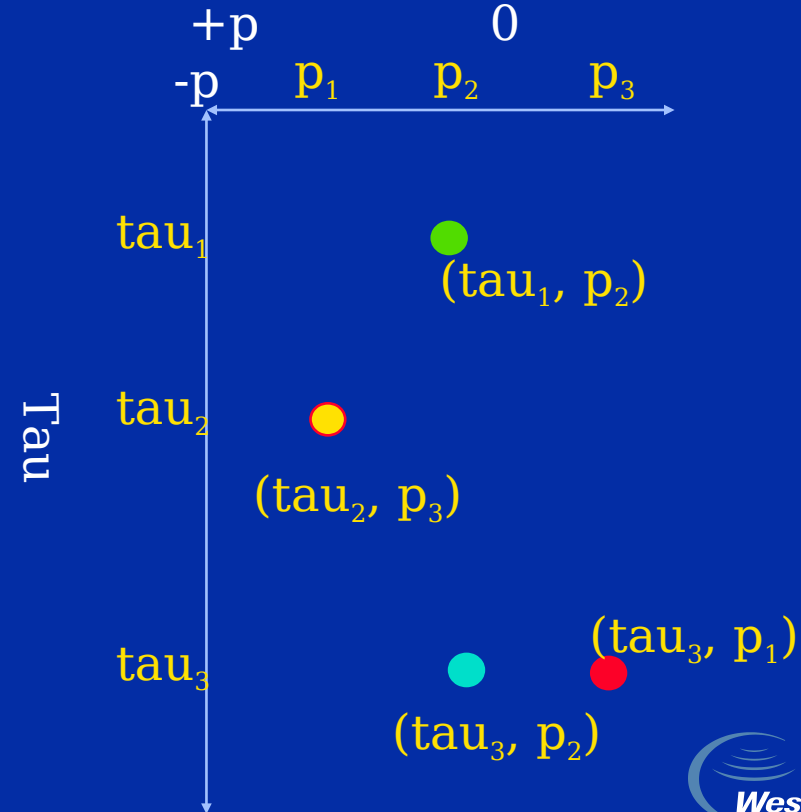
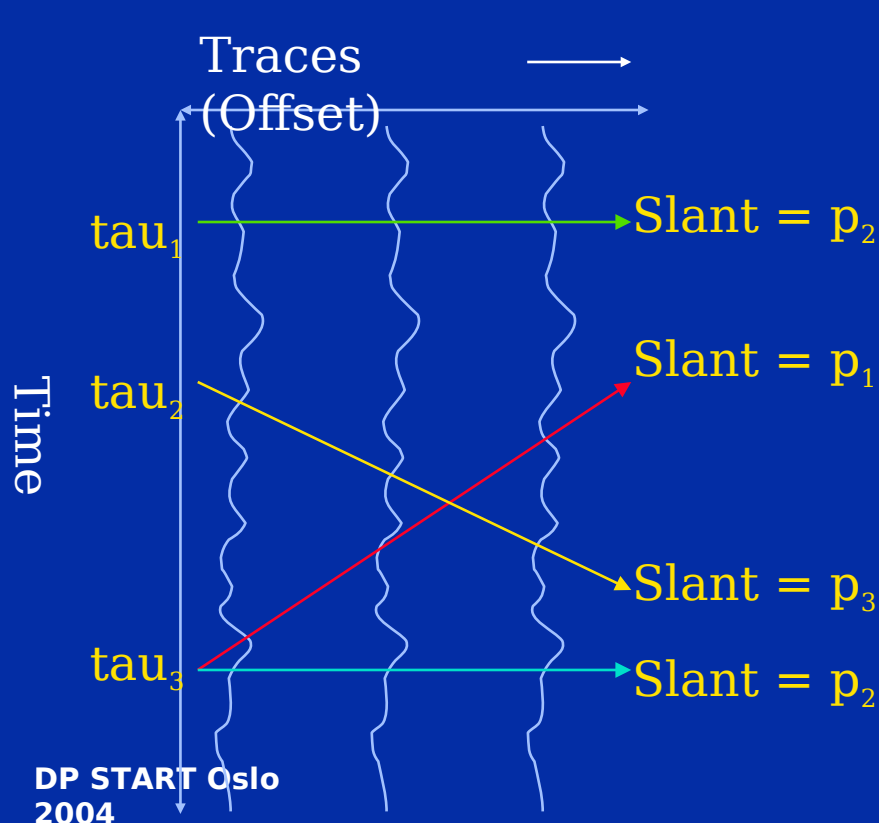


Tau-p Domain

- So what is Tau and what is P
- Tau represents intercept time at zero offset
- P represents dip. The larger the dip of an event in the x-t domain the higher its P value in the Tau-P domain. Flat events (our primaries) appear around $P=0$ in the Tau-P domain.
 - $P = \Delta t / \Delta x.$

Conversion examples - Diagram

- The zero offset time of the slant path is **Tau**
- The slant (moveout, 1/velocity, slowness) is **P**
 - A slant whose time increases with offset is $+P$
 - A slant whose time decreases with offset is $-P$



Tau-p Domain

Several processes are achievable in the tau-p domain, the most common being -

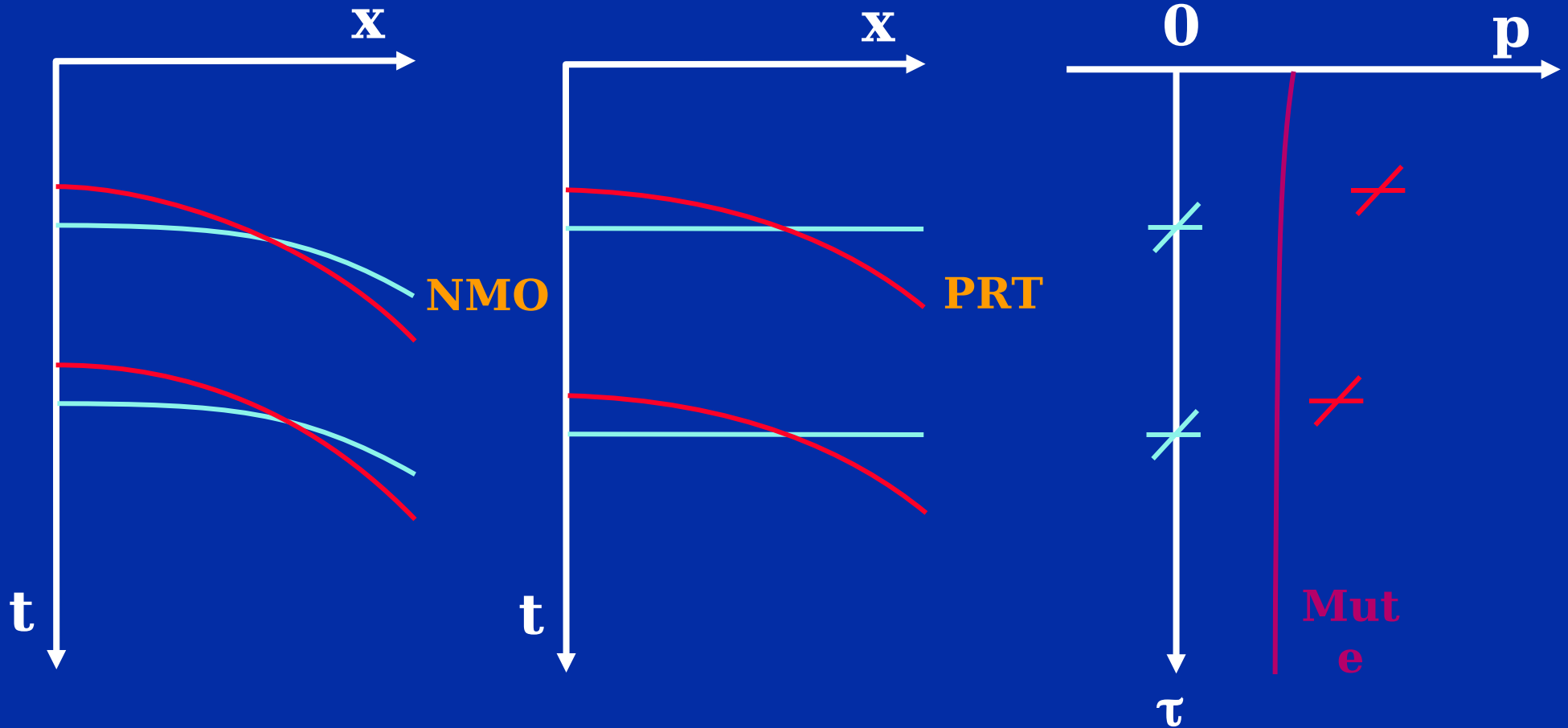
- **Velocity filtering** - events with different dips in T-X will have different 'p' values which can be muted/filtered.
- **Demultiple -Parabolic Tau-p transform** is more commonly used for multiple attenuations.
- **Deconvolution** - more effective due to short-period reverberations being more periodic (for any one p value)

PRT Demultiple

Multiple attenuations via PRT is generally accomplished in the following way:

- **Input CMP gathered data with NMO applied (primary events corrected with multiples under-corrected)**
- **Transform the data into Tau-p domain**
- **Sum along parabolas as opposed to straight lines**
- **Primary and multiple energy more focused than in F-K domain**
- **Multiples muted prior to transform back to t-x domain or, primaries are muted and the multiples transformed back to time domain for subtraction from original data**

PRT Demultiple

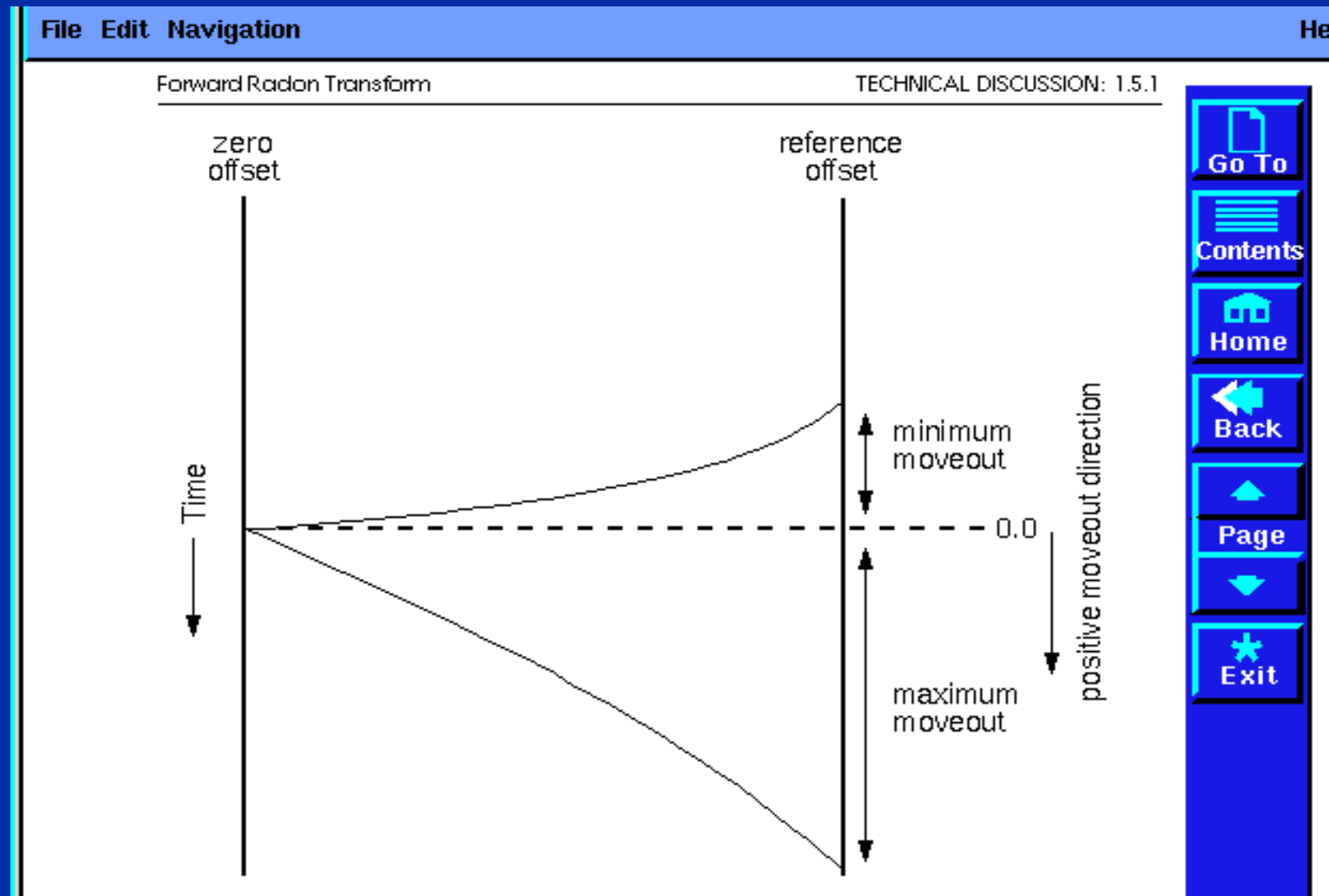


PRT Parameters

Let's look a bit more closely at the parameters for prt:

- **MOVEOUT RANGE:** Minimum and Maximum times define a range for conversion to tau-p domain specified at the reference (maximum) offset
- **P TRACES:** This range is split into evenly spaced parabolas which is defined by the number of P-traces specified in the setup
- **MUTE:** Area in the tau-p domain that is going to be muted ie area with either primaries or multiples

Moveout Range - writeup



Number of P traces

The default number of p-traces is calculated as follows:

$$N_p = 2 (Dt_{\max} - Dt_{\min}) f_{\max}$$

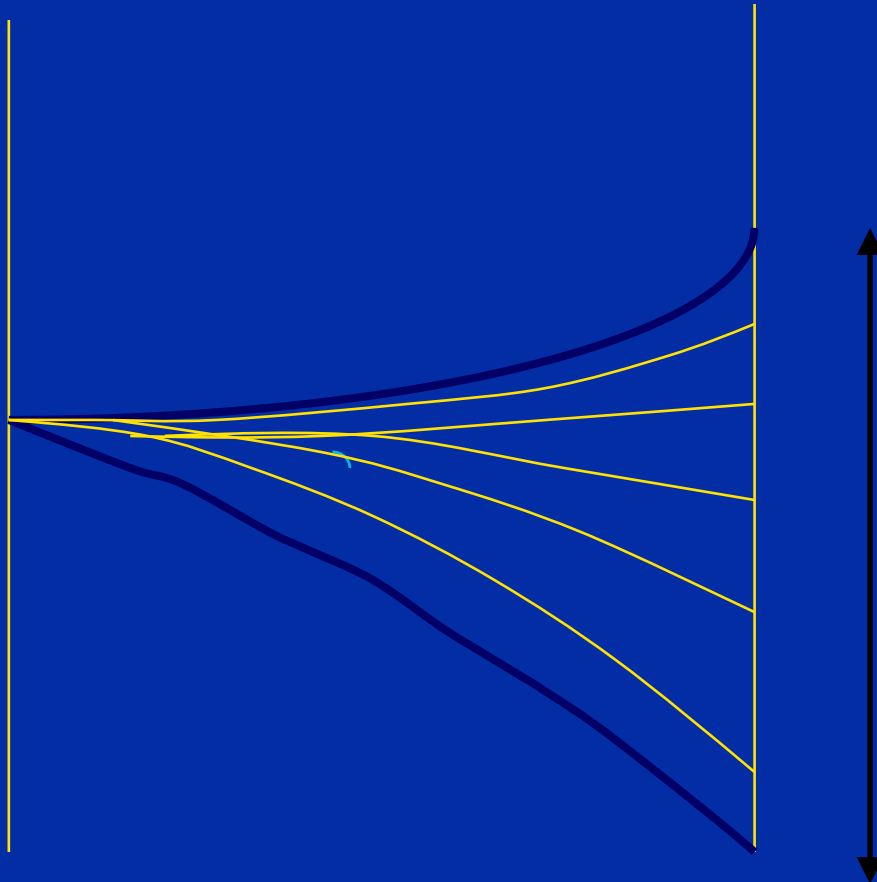
where

- $Dt_{\max}$ = Maximum moveout (seconds)
- $Dt_{\min}$ = Minimum moveout (seconds)
- $f_{\max}$ = Maximum frequency (Hz)
- With reference offset set to max offset for gather

Moveout Range and P Traces

**Zero
offset**

**Reference
offset**

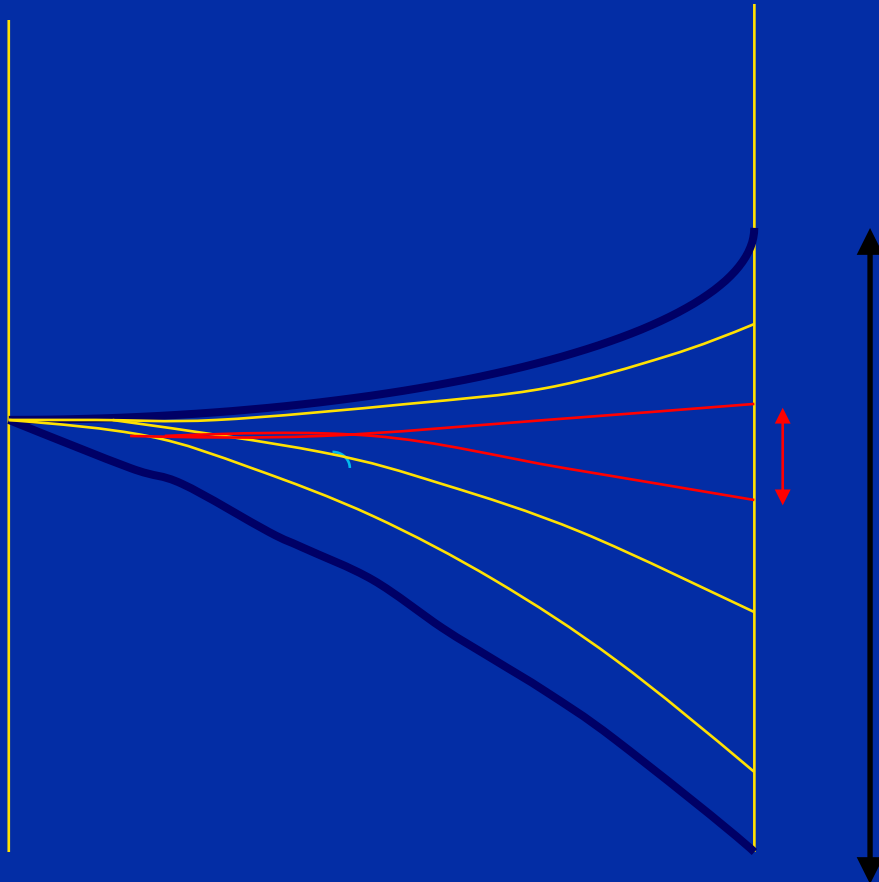


- This example shows 7 p-traces
- The 7 parabolas all start at the same time for zero offset
- They finish at equidistant times which span the Moveout Range

Mute Range

Zero
offset

Reference
offset



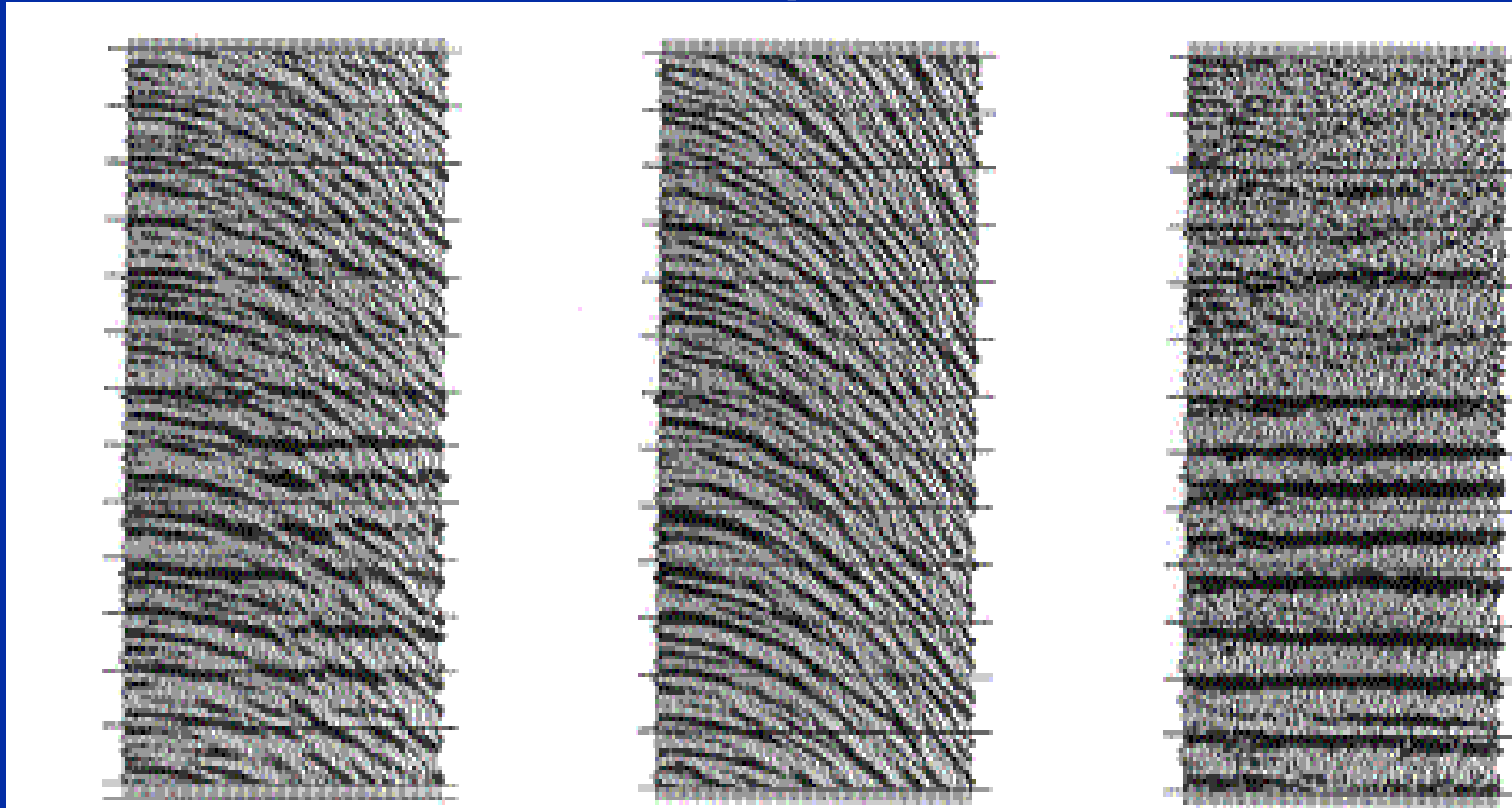
- In this case we are muting the primaries (red area) and leaving the multiples to be subtracted from the original data

Data Example

NMO corrected data

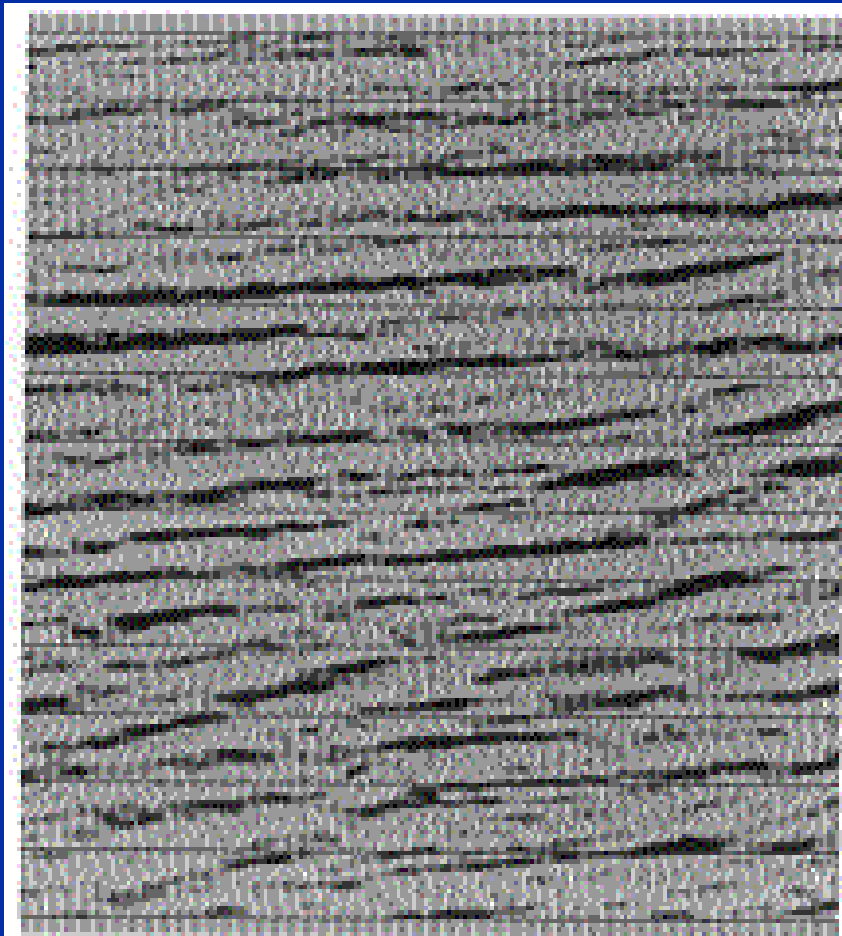
Multiple Model

Primaries

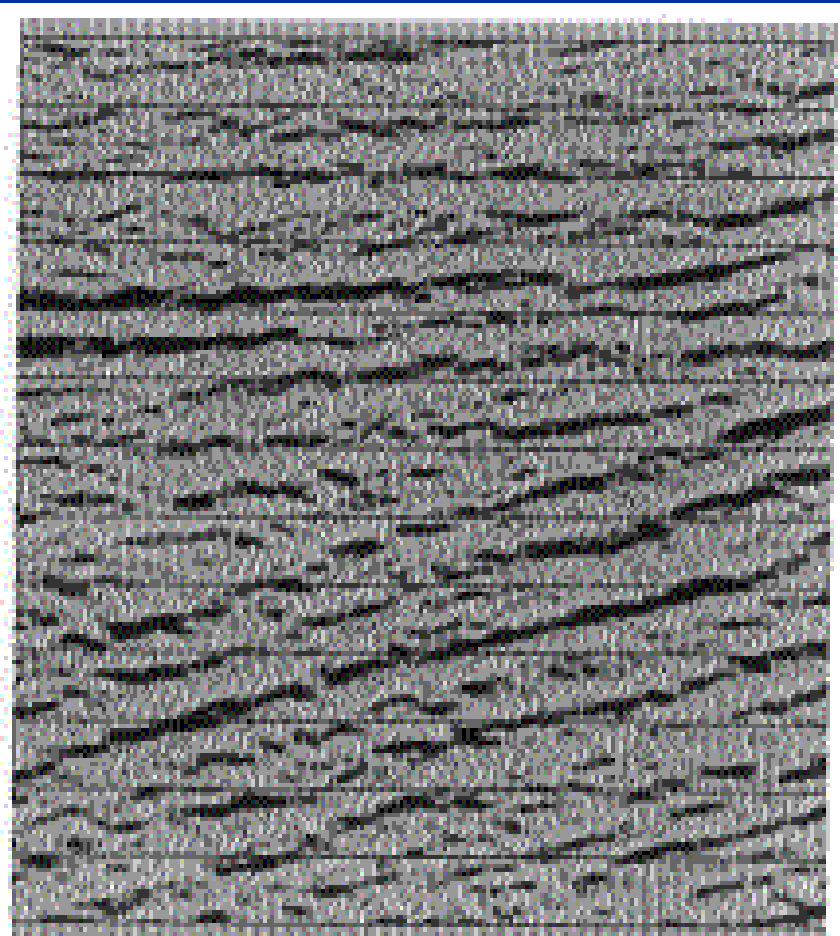


Multiples model is subtracted from the original gather

Stacked Data Example



Before demultiple



After demultiple

PRT Demultiple

- ✓ **Easy**
- ✓ **Reasonably AVO friendly**
- ✗ **Expensive**
- ✗ **Can be difficult to parameterise**
- ✗ **Suffers from aliasing and inversion artefacts**

x-t Predictive Deconvolution

- **Apply predictive deconvolution in time to remove periodic energy**

✓ **Cheap**

× **Poor on far offsets where period is not constant**

× **Statistical**

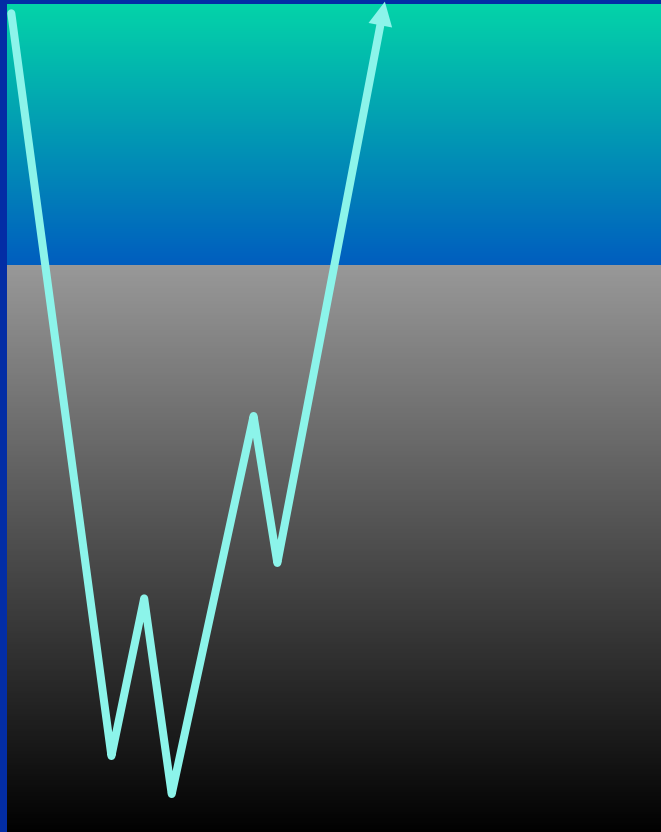
τ -p Predictive Deconvolution

- Apply predictive deconvolution in τ on each p trace to remove periodic energy
 - ✓ Period is constant for horizontal layering
 - × Cost
 - × Period changes with p
 - × Statistical

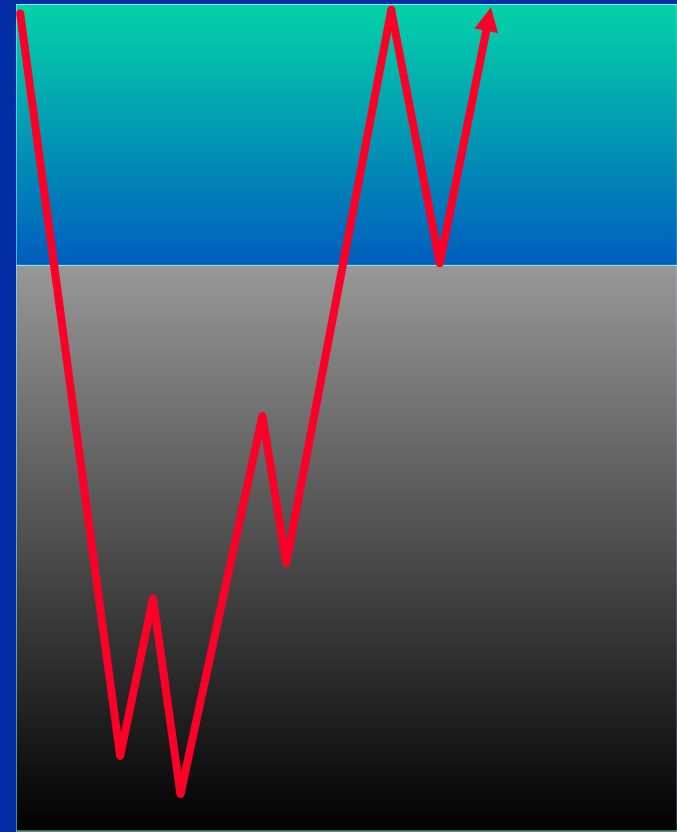
Wave-Equation Multiple Attenuation (WEMA)

- Involves the prediction of water-bottom multiples by wave-field extrapolation - implemented in the FK domain
- Multiple model subtracted from the input data
- Does not predict other types of multiple e.g. inter-bed
- Requires specification of water depths and water velocity

Wave Equation Multiple Attenuation (WEMA)



Propagat



& subtract

Wave Equation Multiple Attenuation (WEMA)

- ✓ Only requires knowledge of water layer
- ✓ AVO preserving
- × Requires simple water bottom
- × Only removes water column multiples

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